Acquisition Core Project 3: Radiofrequency (RF) Pulse Development and Design for High Field MRI

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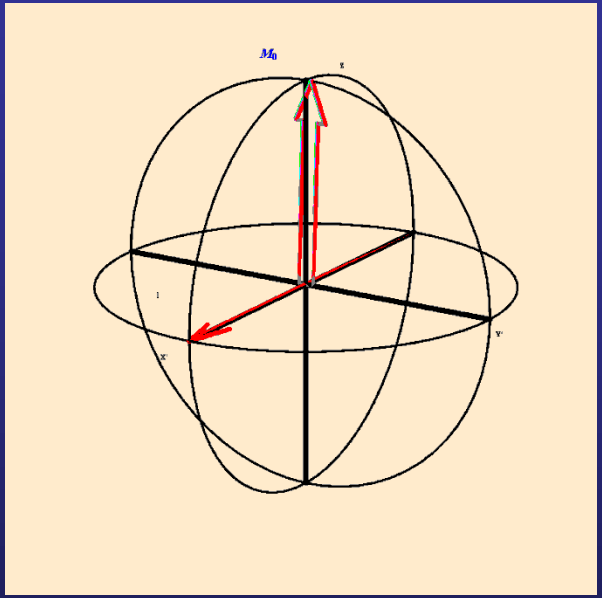
AIMS:

1. Develop RF pulses with immunity to B_1 inhomogeneity and to resonance offset
   - Initial focus on broadband (BB), shallow tip pulses for 3D MP RAGE
2. Expand simulations of magnetization transfer (MT) effects created by the new pulses
   - Initial focus on 3D MP RAGE simulations

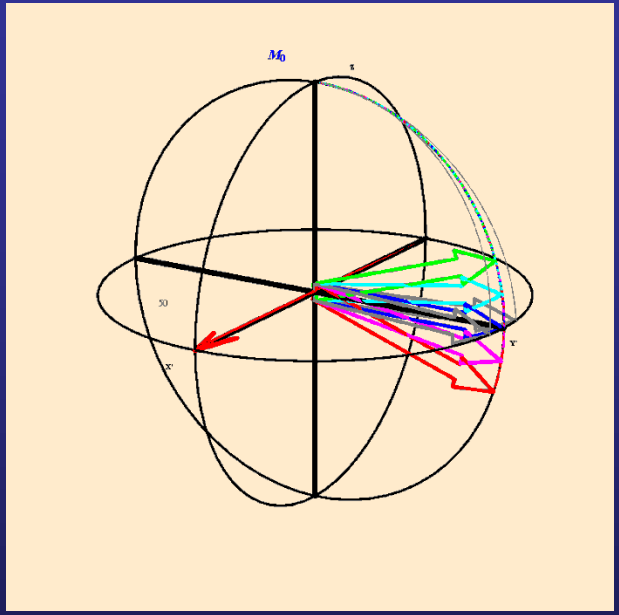
BB Shallow Tip Pulses and 3D MP RAGE Simulations

- Pulse Generation
  - Development of optimal control routine for MatPulse patterned after that described by Skinner and Glaser in articles in JMR
    - Initial pulse (Parent pulse) submitted to optimal control routine in MatPulse
- Magnetization Transfer Simulations
  - Simulations based on formulation by Helms and Hagberg in Concepts in Magnetic Resonance

Parent Pulse Cascade – Null Pulse Version
First and Second Pulses



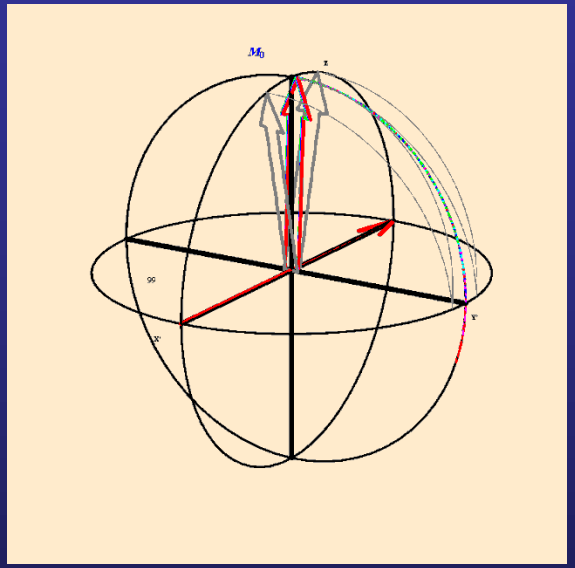
First pulse of parent pulse



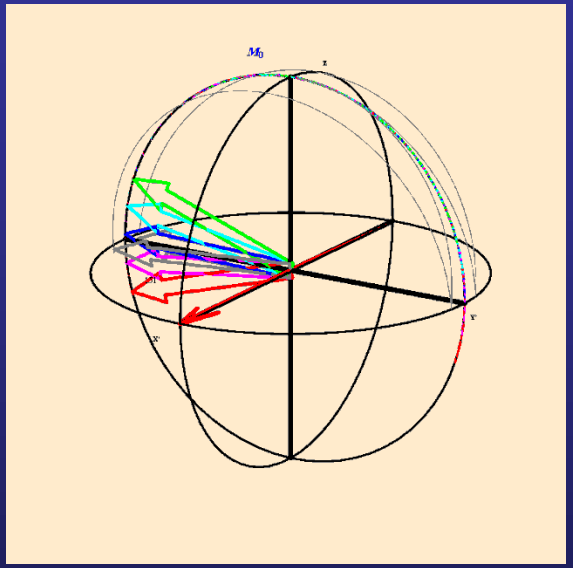
First and second pulses of parent pulse

Trace diagrams of magnetizations experiencing different B_1 fields (color) and different resonance offsets (gray).

Parent Pulse Cascade – Null Pulse Version Third and Fourth Pulses



First three pulses of parent pulse



All four pulses of parent pulse

The trace diagram shows that magnetizations experiencing different B_1 fields (color) are coalesced half way through the pulse, and again at the end of the pulse, while magnetizations experiencing different offsets (gray) are coalesced at the end of the pulse.

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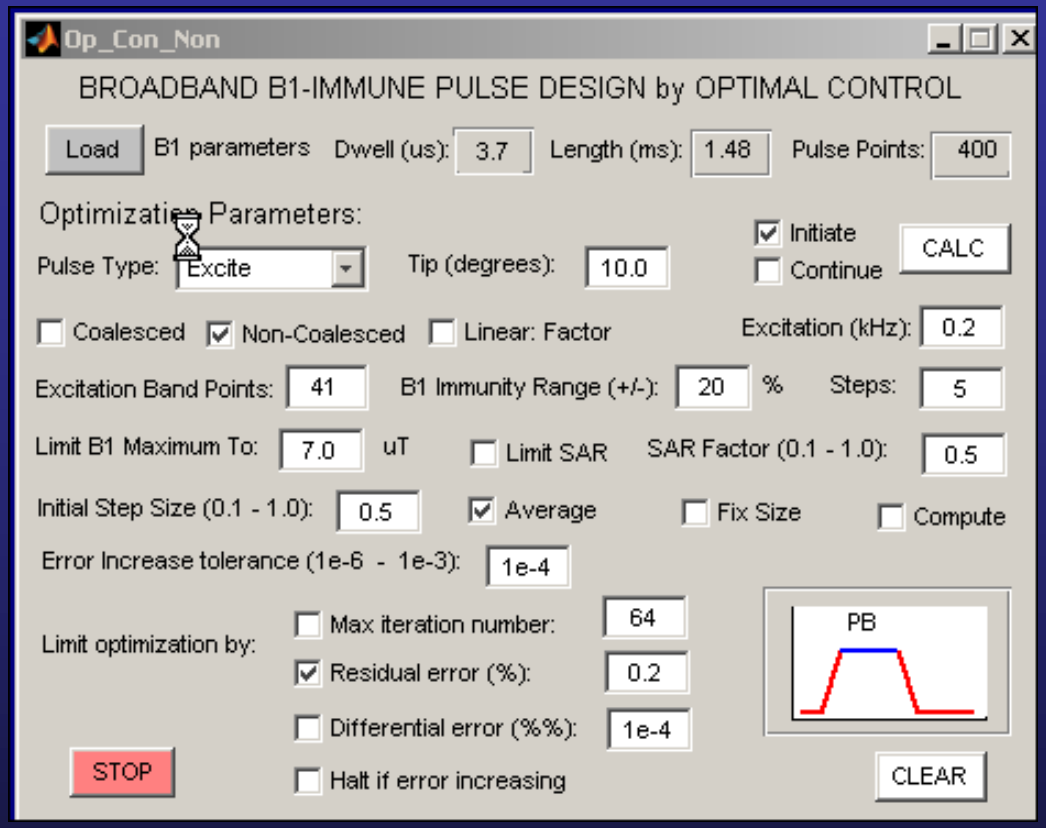
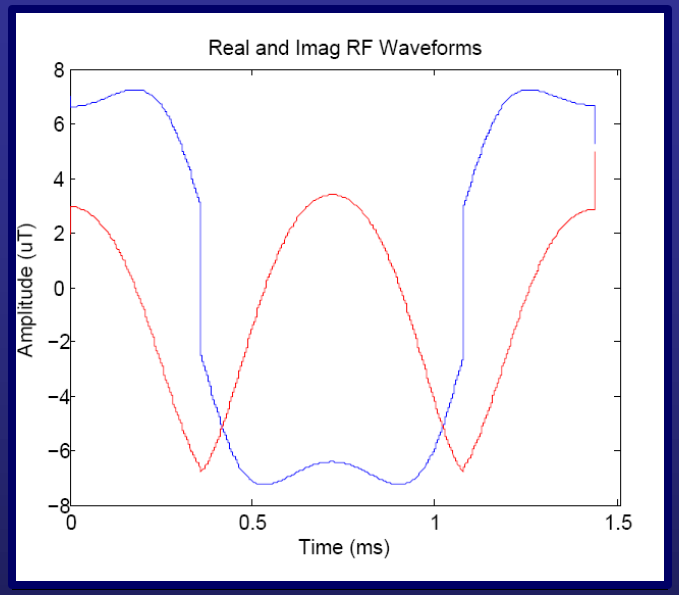
Optimal Control Menu in MatPulse

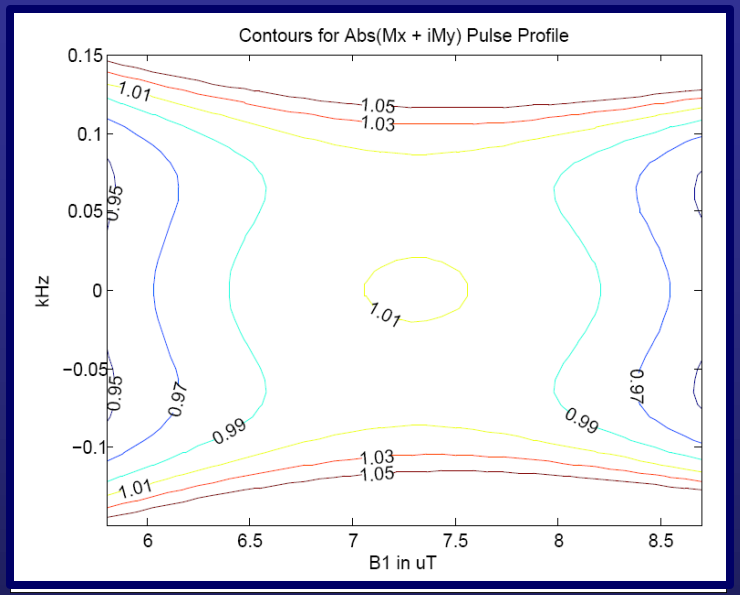


The MatPulse menu showing the inputs for pulse optimization by optimal control

Example of Broadband (Non-Slice Selective) 10 Degree Tip RF Pulse Suitable for MP RAGE



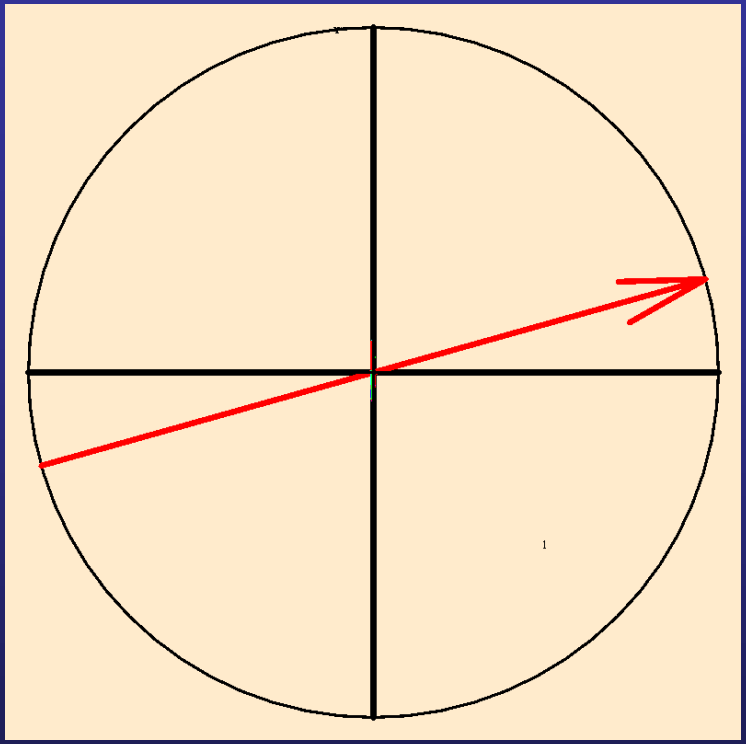
Real and imaginary components of RF pulse.



Contour plot of pulse performance.

The pulse performs well over a B_1 range of +/- 20%, and over a resonance offset range of +/- 100 Hz. This range is suitable for 4.0 T.

Trace Diagram of the 10 Degree Pulse



Trace diagram of the 10 degree pulse (viewing the unit circle from above the z-axis) .

The trace diagram shows that magnetizations experiencing different B1 field strengths (color) are coalesced halfway through the pulse, and again at the end of the pulse, while magnetizations at different resonance offsets (gray) are coalesced at the end of the pulse.

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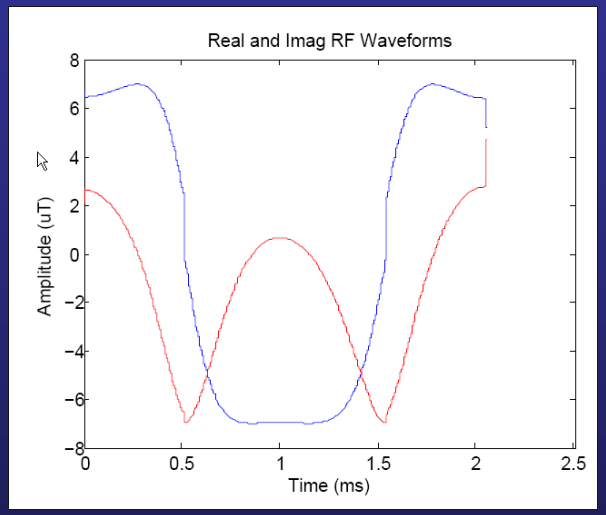
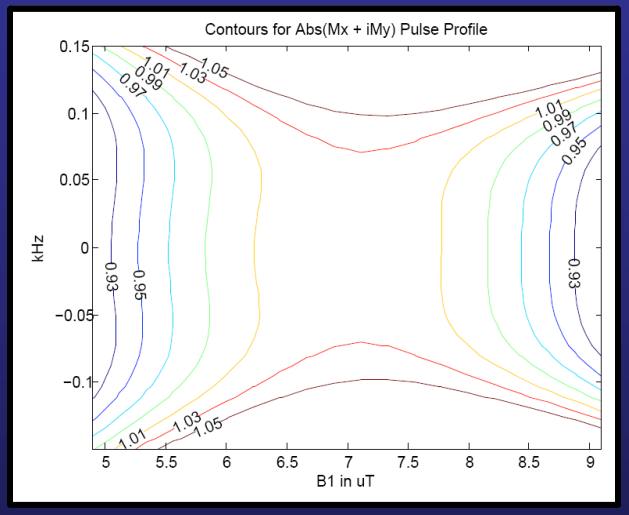
Example of Broadband (Non-Slice Selective) 30 Degree Tip RF Pulse Suitable for MP RAGE



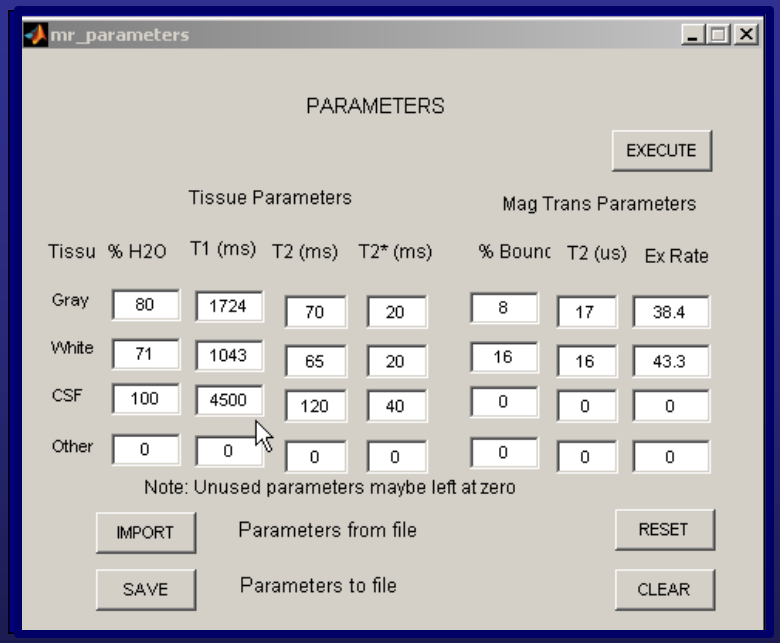
Real and imaginary components of RF pulse..

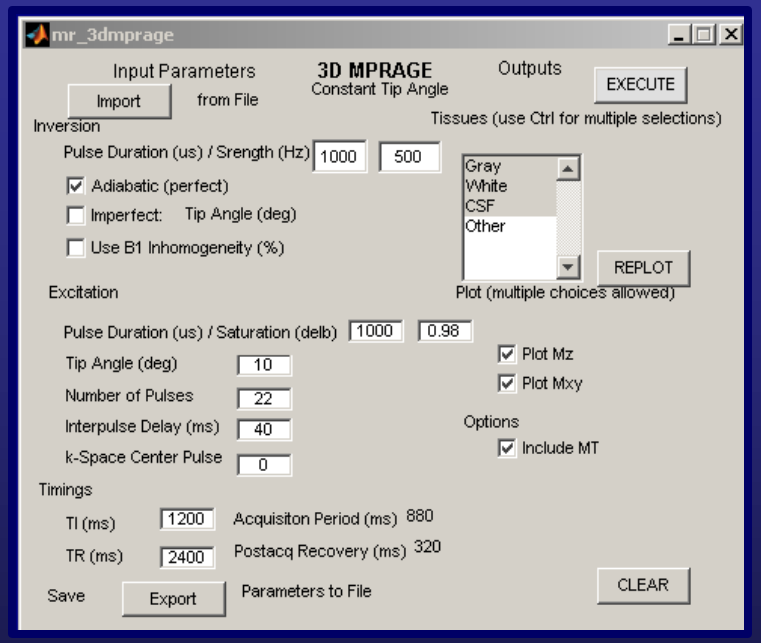


Contour plot of pulse performance.

The pulse performs well over a B_1 range of +/- 30%, and over a resonance offset range of +/- 100 Hz. This range is suitable for 7.0 T.

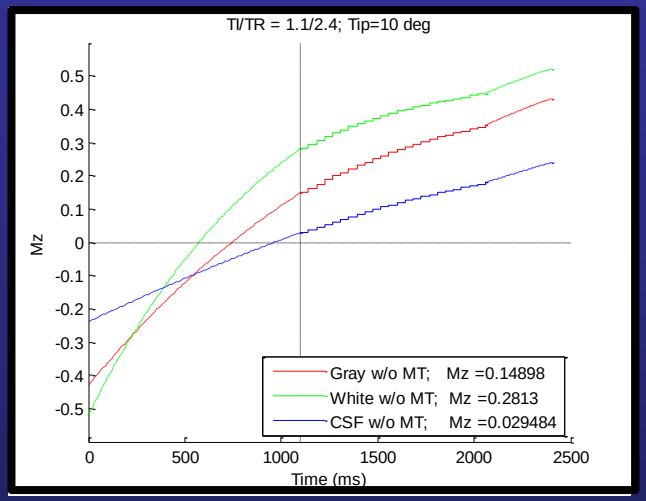
Magnetization Transfer Menu for 3D MP RAGE in MatMRI



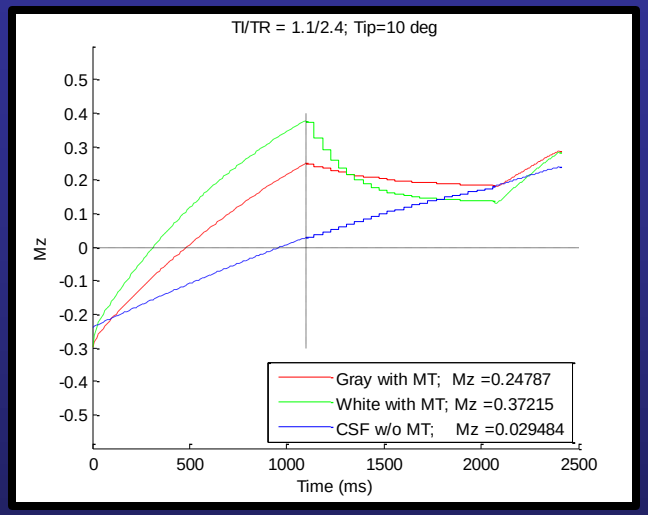


The MatMRI menus showing the inputs for the magnetziation transfer simulations

Simulations of an MP RAGE Experiment with and without Magnetization Transfer (MT) Effects



Simulation of an MP RAGE experiment showing Mz without MT effects



Simulation of an MP RAGE experiment showing Mz with MT effects

- MP RAGE experiments will have to be re-designed to accommodate the greater SAR and larger MT effects associated with the new shallow tip pulses.

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Summary

- Broadband (non-slice selective) pulses are demonstrated with immunity to B_1 inhomogeneity and to resonance offset
- The pulses can be used for 3D MRI experiments such as 3D MPRAGE
- The new pulses are much longer than the rectangular pulses they replace, thus producing more SAR and inadvertent MT effects
  - MRI sequences will have to be re-designed with fewer pulses to accommodate the increased SAR and to mitigate the large MT effects
  - More k-space data must be collected following each pulse to avoid lengthening the duration of the MRI experiment
    - Corrections to the k-space data will have to be applied due to the long readouts

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